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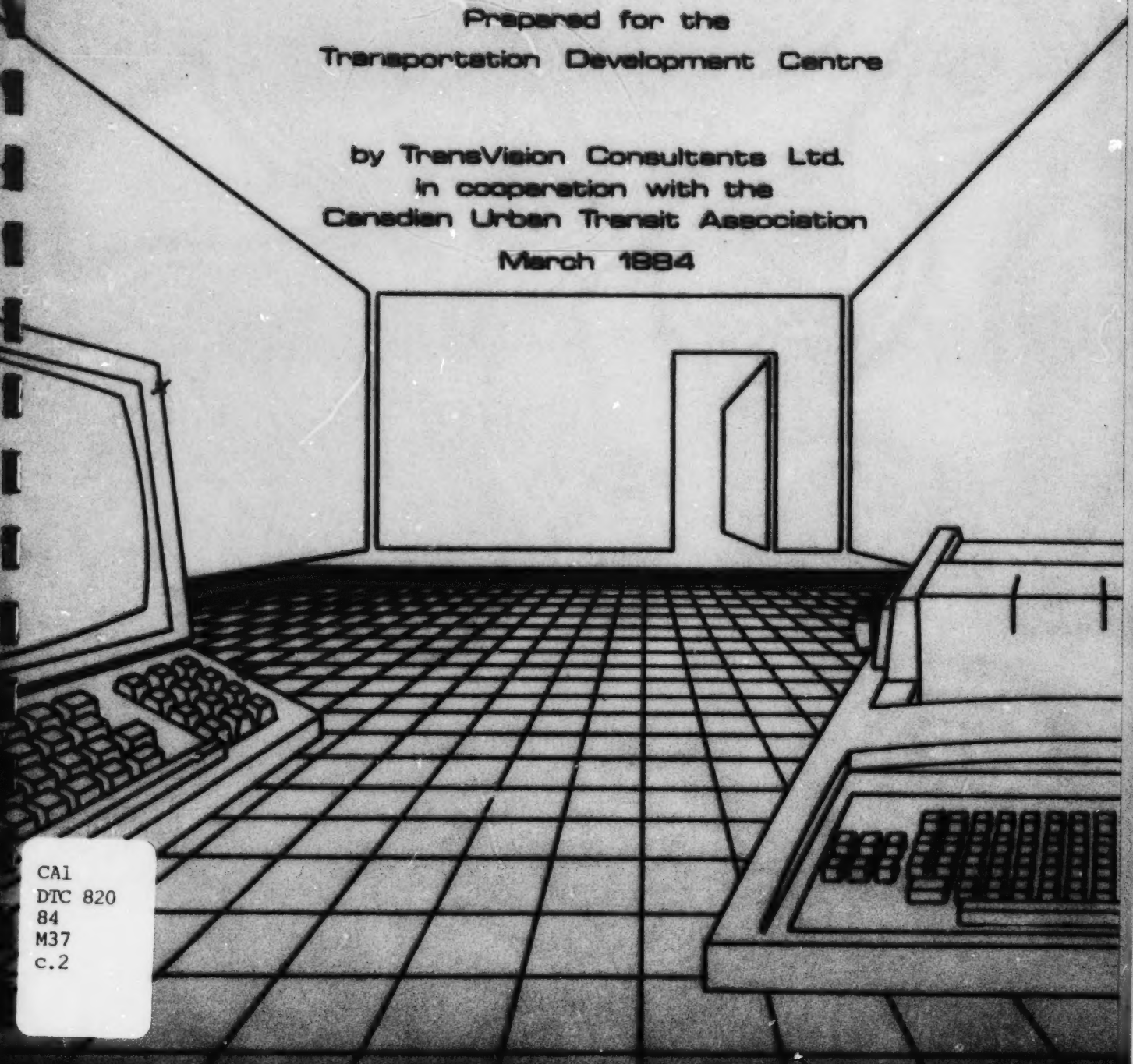
MICROELECTRONICS AND URBAN TRANSIT

Prepared for the
Transportation Development Centre

by TransVision Consultants Ltd.
in cooperation with the
Canadian Urban Transit Association
March 1984



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Al Cormier, Executive Director
Canadian Urban Transit Association
140 Bay Street, Suite 220, Union Station
Toronto, Ontario
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Dear Mr. Cormier:

RE: REPORT ON MICROELECTRONICS AND URBAN TRANSIT

TransVision Consultants Limited is very pleased to submit the final draft of the report, "Microelectronics and Urban Transit", for your approval and distribution to the membership of the Canadian Urban Transit Association.

We would like to take this opportunity to thank the Association very much for the tremendous assistance provided in the prepartion of this report, and a special note of thanks to Charles Wheeler for his excellent support, comments and assistance. The support provided made the report that much more enjoyable to prepare.

We trust that the report will prove of interest to the membership and that the contents will stimulate discussion and new concepts for improving urban transit operations in Canadian cities. It is a very exciting technological era that we are being pushed into, and it is hoped that reports such as this one will lessen the amount of 'push' that is required.

TransVision Consultants greatly appreciated the opportunity of working on this report and would like to say, that if the opportunity arises again in the future, we would be most pleased to participate with CUTA in other work.

Again, thank you very much.

Respectfully submitted,

TransVision Consultants

Jim Geehan

T. E. Geehan
President

attach: master copy
3 xerox copies

MICRO-ELECTRONICS AND URBAN TRANSIT

A Report for the
Transportation Development Centre
by TransVision Consultants Ltd.
in cooperation with the
Canadian Urban Transit Association
March 1984

The contents of this report reflect the views of the contractor and not nessarily the official views or policies of the Transportation Development Centre.

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17 Abstract

This report documents the current state-of-the-art in the application of microelectronics to the urban transit industry for information, communications and control functions. The report includes a brief but comprehensive review of the hardware and software available in Canada, and to a lesser degree in the United States and Europe. The basic functions of data acquisition, recording, transferring, processing, reporting and dissemination are examined as part of an integrated framework. It was intended to stimulate discussion within government and the industry of the applications, impediments and implications of microelectronics. The primary method of data collection was a literature review and contacts with selected suppliers and users. The results of a CUTA questionnaire on computer application in the transit industry was used as a reference document.

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17 Resume

Ce rapport est un documentaire sur les applications les plus avancées de la micro-electronique dans le transport en commun pour l'échange d'information, les communications et les opérations de contrôle. Le rapport comprend une revision du logiciel et de l'équipement disponible au Canada et, en partie, du logiciel et de l'équipement disponible aux Etats-Unis et en Europe. Les fonctions de base de l'acquisition de données, de l'enregistrement, de la transmission, du traitement, de la génération et distribution de rapports sont examinés dans le contexte d'un ensemble integral. Le but de ce rapport est de stimuler des discussions, au sein des gouvernements et de l'industrie, sur les applications, les obstacles et sur les conséquences de la micro-électronique.

Les sources d'information utilisées pour le rapport furent premièrement les nombreux documents existants ainsi que les personnes clés employées par les fournisseurs et utilisateurs. Les résultats d'un questionnaire de l'ACTU sur les applications de l'informatique dans le transport en commun furent aussi utilisées comme réference.

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1. INTRODUCTION

To a much greater extent than other technologies, the technology of microelectronics affects the very essence of urban transit operations since both are intrinsically related to the information-requisite functions of communications and control.

It is precisely this combination of functions that led to most of the present applications of microelectronics in urban transit. The technology first served as parts of computers, a means of handling large quantities of information. To this, applications as parts of communication systems were added. Later, microelectronics found their way into monitoring and control systems. Now, applications are being linked to provide a network of integrated functions.

There are many reasons for adopting this new technology but the main one is the increased availability of more reliable, useful and timely information on which to base decisions -- decisions that affect the level of service and resulting costs and revenues. Better quality information provides the impetus and rationale for implementing improvements in transit operations related to system control, customer service, communications, and other productivity-enhancement pursuits.

Without instruments to collect and process this information, there can be no efficient data acquisition; without devices responding to, and communicating, the readings of the instruments, there can be no system control; without mechanisms to process and analyse the data, management cannot be efficient. New microelectronic-based equipment provides the means of doing all of this with greatly enhanced system capabilities and reliability.

The small size of microelectronic devices has been important in many applications, but the major impact of this new technology has been to make electronic functions more reproducible, more reliable and less expensive. With each technical development, costs have decreased and the ever lower costs have promoted a widening range of applications. In most industries, the quest for technological advances has been required by economic competition and compensated by economic reward.

The adoption and rate of diffusion of the technology in urban transit, however, is extremely diverse but generally quite slow. It appears to be due as much to management's capabilities to adopt and adjust to the technology as it is to economic, political and technical reasons. Transit managers have developed particular skills and talents which are usually not related to the application of high technology. Electronics engineers and computer scientists, on the other hand, are continuously working with a technology that doubles in complexity every two years. There appears to be a growing dichotomy between those who understand the nature and workings of the technology and those who do not.

A more intensive dialogue between the two is required to enhance the understanding of the nature of microelectronics and their role in urban transit. The intention of this report is to stimulate that dialogue and to encourage further discussion within government and the industry with respect to the application of microelectronics in urban transit and its concomitant implications.

This report addresses the issue by presenting a brief but comprehensive review of the state-of-the-art of the application of microelectronics in urban transit information, communications and control systems.

AN INTRODUCTION TO MICROELECTRONICS

Today, a relatively new technology is providing the greatest benefit in the processing of an intangible commodity: information.

Information, in its broadest sense, relates to any and all facts that are communicated, learned or stored. Information technology refers to those technologies that are relevant to communication and control processes and to the handling of what is conveyed in those processes -- that is, information.

Information technology is based mainly on a variety of microelectronic devices. The central one is the integrated circuit. With the

development of integrated circuits in the early 1960's, the central processing unit of a computer can be placed on a silicon chip and then programmed to carry out a complex series of functions. This is a microprocessor, which is essentially a very small, silicon-chip device used to process information. Unlike previous electronic devices, the integrated circuit accomplishes the necessary separation and interconnection of transistors and other circuit elements electrically, rather than physically. This means, in fact, that a brain and a memory can be provided in an unbelievably small space for any piece of equipment and at a modest cost.

Microelectronics, through the new information technologies and the microprocessor, are being introduced into many different areas of society for storing, manipulating and communicating information. At the same time, information-related activities are becoming more important with the result that the technology is expanding at an ever-increasing pace. These developments are often referred to as the microelectronic revolution.

Most of the technological achievements of the past decade have depended on microelectronics. Small and reliable sensing and control devices are the essential elements in the complex systems that guide the space shuttle and the cruise missile. Microelectronic devices are also the essence of new products ranging from communications satellites to hand-held calculators and digital watches. Somewhat subtler, but perhaps more significant, is the effect of microelectronics on the computer. The capacity of the computer for storing, processing and displaying information has been greatly enhanced. Moreover, for many purposes the computer is being dispersed to the sites where it is operated or where its output is applied: to the 'smart' typewriter or instrument or industrial control device.

The microelectronics revolution is not just a quantitative evolution: smaller and smaller electronic components performing increasingly complex electronic functions at ever faster speeds and at ever lower cost. It is also a qualitative technological revolution: the integrated microelectronic circuit, which has given rise to a qualitative change in human capabilities, is a qualitative change in technology.

This qualitative change in capabilities is starting to have an impact on urban transit. The innovations brought by the application of microelectronics in transit is related to the quantity and quality of information that can be provided -- which is the principal product of the technology. More information is available than ever before, and it can be transmitted and acted upon more rapidly. By streamlining and improving the flow of information, the technology of microelectronics is bringing about considerable changes in urban transit.

THE SETTING FOR ITS APPLICATION

Over the years, transit agencies have sought to plan, execute and control complex operations by setting up large bureaucracies with many levels of responsibility. In some transit properties, there are as many as 14 layers of personnel in the chain of command from the chief executive officer to the bus driver (1).

The hierarchial structure of the transit agency enables its management to direct the overall operations of the company, but the organizational distance between the top and the bottom makes it difficult to keep track of labour and equipment resources, to schedule their deployment effectively and to monitor and control their operations. Moreover, a hierarchy can give rise to institutional barriers between departments and can inhibit the internal flow of information.

The organizational barriers to information flow in the transit agency are often supplemented by physical ones. Written and verbally-transmitted information is subject to delay and misunderstanding as it passes from one person to another. The time required for a memorandum or directive to circulate can make prompt corrective action difficult, if not impossible.

These organizational and physical barriers to information flow in transit agencies do not necessarily mean that informatization and bureaucratization are not congenial processes. Both are rooted in highly formalized structures with extensive information and reporting requirements. This obvious parallelism of informatization and bureaucratization strongly indicates that transit management has been long aware of the need for improvements in the collection of data and the flow of information.

In an effort to improve the handling of information, transit management in Canada began looking at the computer in the early seventies. The first applications were the recording of routine financial transactions such as accounting and payroll, but gradually computers were applied to other tasks, such as materials management, vehicle maintenance planning and control, vehicle scheduling, service planning and driver runcutting. Gradually the applications diversified and transit agencies began adapting microelectronics to other needs.

One of the earliest attempts was the development of automatic passenger counters to provide automatic data input to RUCUS, the computerized scheduling program. Efforts to apply microelectronics in other areas began a few years later. The first prototype electronic farebox was developed in 1974 and was the forerunner of the modern registering fareboxes. Location detection using signposts and/or odometers began to advance in concert with the development

of automatic passenger counters and the United States federally-sponsored automatic vehicle monitoring program in the United States. Similarly, data transmission via radio and data recording via solid-state memory advanced rapidly during the latter half of the seventies. In the early eighties, automated passenger information systems became practical.

Almost every functional area of urban transit from planning to customer information is affected by the introduction of microelectronics. The applications are widespread and diverse but they are beginning to be integrated into a network of functions connected by a stream of commonly-available information.

A CONCEPTUAL INTEGRATED APPLICATION

A conceptual view of an integrated network of basic applications is illustrated in Exhibit 1. The components of this integrated network are available in the marketplace and, although some of the components have yet to achieve a desirable level of accuracy or reliability, the experiences of the few transit properties that have pursued the concept of integrated, automated systems indicate the potential for improved information, communications and control.

Integration of the main functional areas of transit -- management, planning, operations, monitoring, maintenance and marketing -- depends on a carefully designed hierarchy of information flow. The linkage of these six areas is being brought about by a centralized processing system, but there are also many kinds of information in each of the areas that need not be centrally stored. Distributed, or decentralized, data processing has become possible recently because of the tremendous growth in microelectronic components and the decreasing cost of storing and manipulating information. In many sectors of the economy, the trend is to disperse powerful minicomputers and microcomputers to the individual workers, making each worker responsible for data entry and processing control. Computers can then be linked to one another and to the central data base of the company by a communications network.

Given the capabilities of existing technology, it is possible to imagine in some detail how a transit information system could operate if several areas of operation were linked in interdependent modules. Various sensors on-board the vehicle would collect data on its location, passenger loading, mechanical condition and operational status. This data would be stored in a mobile data control and logic unit before transmission to a host computer at a central monitoring and control facility. At the central site, the data would then be

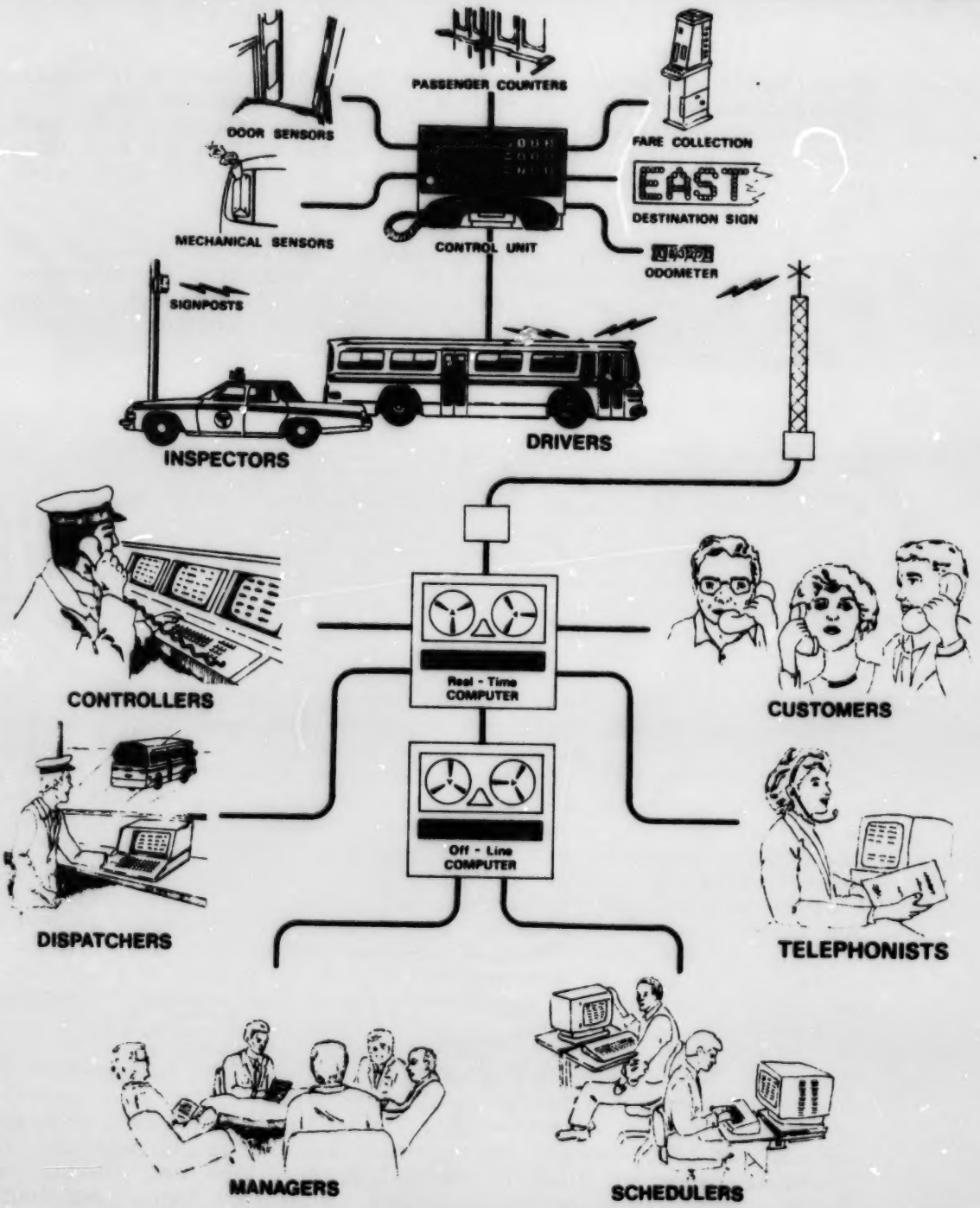


EXHIBIT 1: INFORMATION, COMMUNICATIONS AND CONTROL SYSTEM

processed and analyzed and used directly by a transit controller at the same time that it is stored for later report generation. For example, if all vehicles on a particular route are equipped, a video display can be used to show the controller the progress of the vehicles along the route, their present positions, and how they are performing in relation to their schedule. At the same time, the information on vehicle locations could be disseminated to the public by means of automated telephone information systems. Later, the data could be processed and filtered into a series of reports for management information distribution. This conceptual overview provides some indication of the potential foreseen.

Despite this potential, the systems in use today continue to be essentially experimental and lack one or more of the major elements that would constitute a completely-integrated and automated system. In addition, the number of system designs nearly equals the number of transit properties using them. Until very recently, just about every transit property pursuing the implementation of one of the components has done so on an experimental basis with each developing its own specifications. As a result, each component developed tends to have unique features. Consequently, transit properties are not always able to make the most effective use of the components, nor are they always assured of system reliability and support or benefits from any potential economies of scale.

This diversity has been an unfortunate development for the transit industry since, in many cases, the application of microelectronics meets a universal requirement and there is little need for systems to develop independently of each other. Recognizing this fact, the Ontario government, for one, is attempting to develop and implement a modular, flexible, comprehensive package of products to satisfy the information, communications and control needs of the transit industry.

But even with this latter development, the full potential for integrated and automated information, communications and control systems is just starting to be tapped -- as will be seen in the state-of-the-art review on the following pages of this report.

2. DISSERTATION

A brief review of the state-of-the-art of the basic components of transit information, communications and control systems is provided in this chapter. The review focuses on the following basic functions of an integrated, automated system:

- **Data Acquisition** - automatic collection or acquisition of vehicle status or operational data with the aid of a variety of possible microelectronic-based sensing devices.
- **Data Recording** - recording, validation and temporary storage of the data acquired by means of a vehicle-mounted, microprocessor-based control unit.
- **Data Transferring** - transferring of the data from the mobile control unit to a central computer using digital radio transmission or other data communications system.
- **Data Processing** - processing of the data file from the bus into information that is useful for supervision, monitoring and control of the transit service.
- **Data Reporting** - analysis of the data and preparation of reports suitable for planning, marketing, maintenance, monitoring and other management purposes.
- **Data Disseminating** - filtering of the data into useful information on the status of the service for easy and automated access by potential customers of the service.

Data Acquisition:
DATA ACQUISITION SENSORS

A wide variety of data acquisition sensors are available to obtain data automatically on passenger counts, location measurement, vehicle mechanical status, passenger fare payment, emergency alarms and so forth. Consideration has been given by transit properties to monitoring oil and air pressure, engine temperature, passenger load, vehicle speed, time and location with microelectronic devices such as thermocouples, strain gauges, photoelectric cells, sound transducers and other sensing devices.

In an effort to develop some uniformity in design, the United States National Cooperative Transportation Research Program recently undertook a project to develop functional specifications for on-board, automatic data collection systems (2). The NCTRP project advocated a modular approach, the premise being that the system could then be configured to individual users' requirements by selecting and implementing only those modules desired. The modular approach would permit manufacturers to offer standardized modules and would likely encourage single-module manufacturers to enter the market. Yet, the modular approach would retain the data collection flexibility associated with more customized approaches.

Standards are also being developed in the United States for a communications interface protocol between onboard microcomputers and sensors, activators and peripherals by a joint committee of representatives from the American Trucking Association and Society of Automotive Engineers. These standards are being developed for heavy trucks, but may later be applied to buses.

Some of the peripherals, or data acquisition sensors, that have been suggested in various studies include: automatic passenger counters, automatic vehicle location systems (odometers and radio signpost transmitters/receivers), automatic fare collection systems (pass readers and registering fareboxes), mechanical status indicators (oil pressure, engine temperature, etc.), electronic destination signs, silent emergency alarms, and keypads for manual data input.

The main data acquisition sensors in urban transit are described in the following paragraphs:

Automatic Passenger Counters (APC's)

Basically, APC systems include the instrumentation to collect data on the number and location of passengers boarding and alighting the vehicle and the mechanisms to process it into useful information.

In order to collect this data, special equipment is required. A vehicle fully-instrumented for automatic passenger counts generally requires: front and rear door passenger sensors; front and rear door-open/door-closed sensors; a special odometer; possibly a signpost receiver; and, either an on-board recording device, or a conventional two-way radio with appropriate interface electronics for digital, data communications.

The central piece of equipment, however, is the passenger sensor. During the last decade, numerous devices from wire strain gauges for measuring vehicle load to seat contacts for determining vehicle occupancy have been tested. Several devices that were tested in the mid-70's never advanced beyond the prototype development stage (3). These included an ultrasonic beam interruption system developed by the Automatic Switch Company, an acoustic echo-ranging system developed by the Vitro Laboratories Division of Automation Industries, a multi-switch treadle-mat system developed by Scope Electronics Inc. and a pressure-sensitive mat system produced by Honeywell Inc.

The more successful early experiments were the ones that used either infrared light beams or pressure-sensitive treadle mats to detect passenger movements through the doors. Two (or more) beams or mats are required for each passenger stream. The order in which the beams are broken (or the mat contact made) determines whether the passenger is boarding or alighting.

The earliest large-scale testing of APC systems was done in coordination with comprehensive Automatic Vehicle Monitoring (AVM) systems. In the mid-70's, the General Motors Transportation Systems Division experimented with an AVM system in Cincinnati that used infrared beam counters to record data on passenger boardings and alightings. This system was known as the General Motors Transit Information System (TIS). In late 1981, after nearly ten years of development effort, however, General Motors ceased developing the system as an austerity move and the full Cincinnati system was moved to Windsor. Twenty-seven of the ninety-three coaches at Transit Windsor are equipped for this data acquisition, but difficulties with software modifications and recent developments elsewhere are forcing a reconsideration of the value of the system.

Other potential system suppliers invested a great deal of time and effort in research and development, but still retired from the marketplace. AB Almex was one of the first companies in the field, supplying passenger counting equipment to Stockholm, Dublin and Melbourne in the early seventies, but the company no longer supplies the system, citing the difficulty of obtaining radio communications channels in Europe as a major reason. Dyniman Corporation supplied infrared multi-beam counters to Los Angeles for demonstration purposes

in 1976 but has since withdrawn from the field. Etrometa and Hani-Prolectron are other European companies that have entered and withdrawn from the marketplace over various periods of time during the last decade.

In spite of the uncertainty of APC system suppliers, there have been some notably successful demonstrations of automatic passenger counting systems. In 1974, the Toronto Transit Commission initiated a project to install 100 dual beam passenger counters as a part of its overall Communications and Information System (CIS) program (4). Subsequently a pressure-sensitive mat was tested and approved for use on another 185 vehicles in January 1984. A demonstration in Los Angeles began in 1976 that has seen 200 vehicles on four routes equipped with pressure-sensitive treadle mats for passenger counting. San Mateo initiated a project in 1979 to obtain an AVM system, but with manual input of passenger loading information.

OC Transpo in Ottawa was one of the first properties to successfully use a stand-alone, off-line APC system. This project was initiated in 1976 and it has resulted in 66 vehicles being equipped with dual beam counters and on-board microprocessors to validate and store the data (5). In early 1978, Seattle Metro installed a treadle mat system on 56 buses and in late 1983 began equipping another 63 buses with treadle mats produced by London Mat Industries. Four other Canadian cities have some experience with APC systems. These include Calgary with five units, Quebec City with 17 units, London with 18 units, and Edmonton with two units (now obsolete). Hull is in the process of equipping 30 units as a part of its total system monitoring and control program, and Halifax, with its TransInfo program, plans to equip 145 vehicles with passenger counters. Kitchener Transit is another property looking at passenger counters, planning to equip 20 vehicles in 1984, operating off-line and linked to a minicomputer.

Red Pine Instruments Limited of Ottawa, Ontario has supplied the hardware components for Ottawa, Quebec City, Calgary and Portland and has supplied several units to Los Angeles. The company manufactures infrared light beam sensors of its own design. London Mat Industries of London, Ontario recently developed a pressure-sensitive mat counter that has undergone successful tests in London and Toronto (6) and is currently being installed in Hull, Halifax and Seattle.

In an effort to develop some uniformity in the design and usage of APC systems, the Canadian Urban Transit Association recently undertook a project to develop uniform functional requirements for automatic passenger counting systems. The resulting report was entitled "APC Uniform Functional Requirements Definition" (7). The purpose of which was to encourage better utilization and more stable supply of automatic passenger counting systems.

Automatic Vehicle Location (AVL's)

In essence, AVL systems include the instrumentation to collect data on the location of transit vehicles and the mechanism and software necessary to process the data into useful information.

In order to collect vehicle location data, equipment required includes some form of roadside transponder or transmitter and an on-board receiver (or conversely) to locate the vehicle in relation to a known, fixed point of reference. For real-time vehicle location systems, two-way radio with digital communications, as well as a central control computer with appropriate software and control devices, is required.

Automatic vehicle location systems come in various packages and utilize different means to locate the vehicles, but the main system can be classified as one of two types:

1. **Roadside-based equipment.** Most of the older systems were based on fixed roadside signposts which monitored the passing of each vehicle. Examples of these early systems are the BESI (Bus Electronic Scanning Indicator) system introduced in London in 1958 and a similar system in Paris. An advance on this system was the Motorola system in Chicago. Another roadside-based system is the VETAG system developed by Phillips which is in use in several European cities.

2. **Vehicle-based equipment.** With this system, information on the progress of a bus is registered on the bus itself and passed by radio to a central controller. The information usually comes from an odometer which measures wheel rotations (for example, the CARLA system by Marconi in London and the SECAMA system in Paris). Most new systems are similar to this, but the odometer readings are calibrated by signals received automatically from radio signposts (for example, Toronto, Zurich, Stockholm and Hamburg).

In 1958, London Transport began experimenting with communication aids for bus route control. The first such system was BESI (Bus Electronic Scanning Indicator) which indicated to a central controller when a bus with a special plate on its side passed a series of roadside beacons. Later, in 1973, a more sophisticated system developed by the Marconi Company was tested. This was known as CARLA (Computer and Radio Location Aid) and represented a significant development in automatic vehicle location systems. However, a reliance on voice radio channels limited its expansion and a new system, BUSCO (Bus Communication and Control System) using digital communications was introduced in 1983. In 1960, Hamburg began operation of a bus location system similar to CARLA, using roadside transmitters and on-board receivers. Between signposts, vehicle location information was augmented by odometer measurements. The Hamburg system eventually

developed into a sophisticated bus control system. Other, similar systems have developed in Paris, Stockholm, Zurich and Milan.

In North America, the Chicago Transit Authority was the first transit property to investigate automatic vehicle location. It began a two-year demonstration project in March 1970 with 570 vehicles on the late-night owl services (60 routes) and 120 low-power electronic signpost location transmitters placed at strategic locations. Winnipeg was the next city in North America to investigate automatic vehicle location systems. In 1973, Transport Canada's Transportation Development Agency (now the Transportation Development Centre) entered into an agreement with Winnipeg Transit to determine the degree of accuracy that a random vehicle monitoring system using triangulation might provide in an urban area. The accuracy was very good but the cost was prohibitive. About the same time, in January 1973, the Transportation Development Agency entered into a contract with B.C. Hydro in Vancouver to develop and test a vehicle location system using transponder devices coupled to receiving loops in the roadway. Ten roadside stations and 54 vehicles were equipped and tested over a two-year period but the cost of the receiving loops was too high in comparison to other technologies, and the system was dismantled after the demonstration. In Sudbury, also about the same time, a vehicle location system using roadside transmitters and manual polling of vehicles was developed. This system is still in use in Sudbury.

The Toronto Transit Commission also became involved with automatic vehicle location in 1972 with the prototype development of its Communications and Information System (CIS). This system is based upon an odometer but the positional accuracy is calibrated by reference to signposts at the ends of routes, and also using an algorithm based upon doors opening and closing at known bus stops (similar to the SECAMA system in Paris). All of this enables vehicles to be located to an accuracy of within 12 meters at any time. Mississauga Transit was also involved with vehicle location systems, beginning in 1975. As part of the automatic bus passenger information concept, an automatic vehicle monitoring system was implemented using mobile terminals on the buses, transmitters mounted on signposts along a bus route, and a digital communications interface.

The newest systems in Canada include Hull and Halifax. The Commission de Transport de la Communaute Regionale de l'Outaouais (CTCRO) in Hull is in the process of equipping all of its vehicles and erecting location signposts. The City of Halifax is also developing a similar system for the Metro Transit Commission. Both cities are using location equipment supplied by Gandalf Data Limited of Ottawa.

In the United States, after the initial system development in Chicago by Motorola, the General Motors Transportation Systems Division began

experimenting with automatic vehicle location on the Queen City Metro in Cincinnati using battery-powered radio frequency signpost transmitters augmented by odometer readings (this is the system that was moved to Windsor). In 1976, a demonstration began in Los Angeles that has seen 200 vehicles equipped and 5,000 signposts erected for vehicle location. The Los Angeles system is billed as the Urban Mass Transportation Administration's 'Advanced, Area-Coverage AVM Program'. The large number of signposts was required since testing was undertaken of both random and fixed-route operation. Seattle recently augmented its odometer-based location system with signposts supplied by AVM Systems Incorporated of Texas. Now other cities in the United States like San Antonio are preparing to implement automatic vehicle location systems.

Automatic Fare Collection (AFC's)

Basically, AFC systems include some means of collecting fares and recording the information with respect to fare paid and passenger category and accumulating this information over time for later processing into useful information.

There appears to be several important trends in fare collection. The first trend is that the requirements of more complex fare policies seem to be taking increasing prominence. These requirements are now either pushing conventional equipment beyond the limits of its functional capabilities, or are requiring greater sophistication of equipment. The second trend is towards a systems approach in which fare collection hardware is seen as an integral part of revenue processing, security procedures and data processing (8). The benefits of microelectronics in fare collection are many: production of ridership and revenue profiles, audit trails and various management information reports. Counter-balancing these trends, however, is the concern for simplicity and the scepticism that faces modern fare collection equipment.

One of the biggest problems facing the fare collection industry right now is the processing of dollar bills. Paper money is simply incompatible with the typical coin-operated fare collection equipment now in use. Edmonton Transit is experimenting with a method of using air pressure to force the bills into the vault; other properties use plastic pokers. Coin processing, however, is also becoming a problem. As fares rise to near a dollar, the number of coins that must be processed rises proportionately. In non-registering fareboxes, which are about the only ones found in Canadian transit properties, the number of coins for a bus driver to check is sometimes too great to keep up with, enabling patrons to shortchange the system.

For the aforementioned reasons, the trend in the United States is toward the use of microelectronic technologies in fareboxes to measure and register the individual fare payments. AC Transit in Oakland recently put in a fare collection system manufactured by Duncan Industries and the Dallas Transit System just installed new electronic registering fareboxes on all 600 of its buses in the fall of 1982. Four other major transit properties -- the SCRTD in Los Angeles, the Chicago CTA, New Jersey Transit, and the Baltimore MTA -- have just ordered, or are in the process of ordering, more than 10,000 electronic registering fareboxes (9).

The major suppliers in North America of on-board fare collection systems using microelectronic technology include Cubic Western Data, General Farebox Incorporated and Duncan Industries (which was recently purchased by GFI).

Among the new developments by Cubic Western Data is the testing of a computerized automatic fare collection system for buses called the 'Fast Fare System'. In addition to accepting coins and currency and verifying the amount, Fast Fare is reportedly able to: (1) accept stored-value rides of magnetically-encoded farecards, (2) handle a variety of time-duration passes, along with different types of transfers, (3) generate a variety of audit reports, (4) conduct self diagnosis for maintenance purposes, and (5) enable data capture by electronic probe and/or magstripe card. There is also a voice synthesizer inside the farebox to explain to passengers how to pay their fare (10).

The newest development from Duncan Industries is a probeless data system. Used in conjunction with Duncan's 'keyless cashbox', all data is electronically relayed to the management information system automatically when the cashbox is inserted into the main holding vault. As with other registering fareboxes, Duncan's Faretronic system counts coins and bills and displays fares on a large vertical inspection plate on the farebox for the driver to see. This allows the operator to verify fare transactions for each passenger.

The General Farebox Incorporated farebox is based on four elements: the coin mechanism, coin escrow, bill transport and the logic unit. The base of the computerized unit is made by Motorola, with some modification. A central computer (such as an IBM Personal Computer) is used to record all fare data captured by the microprocessor in the farebox. An electronic data probe is used to extract the revenue information from the farebox as well as input data regarding the destination of the bus, the driver's number, the run number, general data for maintenance and management, and to store any changes in the fare structure.

As the transit industry is increasingly squeezed by the need for more revenues from the farebox, and as the use of the dollar bill becomes more prevalent, greater attention will be focused on electronic fareboxes and other forms of passes such as 'memory cards'.

Various types of memory cards are beginning to generate interest in the transit industry. These are the same size and shape as a credit card but may contain embedded microprocessors, optical stripes for laser recording and playback, magnetic stripes or optical bar codes (11). They have been used previously in France for electronics funds transfer and are being tested in the United States in various roles: in the food stamp program, military 'dog tags', paying for gas at fully automated service stations, etc.

In urban transit, if the cards were coupled with automatic readers on board the vehicles, the benefits would include: better security, greater customer convenience, better planning information, and the possibility of more sophisticated fare structures, or even automatic billing for certain users.

The New York Metropolitan Transportation Authority is currently undertaking a major investigation of different fare collection systems. Consideration is being given to electronically-controlled, stored-value tickets and other memory cards, such as the aforementioned French 'smart card' Telepass (12). Montreal is currently testing a magnetic stripe card reader, and Toronto is planning to undertake some tests of magstripe cards in 1984.

Other Data Acquisition Sensors

Other possible data acquisition sensors that can be used to acquire data on the vehicle status include the following:

Mechanical Status Monitors - These sensors could constantly monitor the mechanical status of the vehicle (oil pressure, fuel level, air pressure, engine rpm's, vehicle speed, coolant level, and so forth). If a real-time system is used, an alarm could be noted at central control when the indicators are above a safe level for a certain period of time. This would allow central control an opportunity to investigate the problem before serious damage results. Another possibility is to record the data from the bus at the servicing island for input into preventive maintenance programs and driver performance monitoring. General Railway Signal and Engler Vehicle Management Services have developed components for this type of mechanical monitoring system. The CTCRO in Hull appear to be the first property in Canada to incorporate mechanical alarms into its vehicle monitoring

system and the TTC in Toronto extracts maintenance data from its vehicles that are equipped under the CIS program.

Electronic Destination Signs - Electronic destination signs are available as a commercial add-on product from various manufacturers such as the Luminator Division of Gulton Industries and Pachena Scientific and Industrial Electronics of Burnaby, B.C. Calgary is one of a number of cities that have tested electronic destination signs. Although the initial cost is almost four times standard roller signs, the capacity, flexibility, durability, low maintenance and updating costs, and ease of maintenance make them desirable for some properties. OC Transpo in Ottawa is currently experimenting with a single electronic control device to permit the driver to change all seven roller signs at the three locations on the bus (front, side, rear) automatically to eliminate the delays caused by manual changes.

Silent Emergency Alarms - These types of alarms are becoming more and more important to transit properties throughout North America. In Los Angeles, for example, the reason cited for expansion of their AVM system is for automatic emergency location of vehicles. In these instances, a covert switch is provided for the driver to use in the event of an emergency. The mobile control unit and radio system is used to transmit the alarm to central control. It could probably also be connected to the electronic destination sign to flash an emergency message.

Traffic Signal Priority - Some properties, such as the TTC in Toronto, are investigating the possibility of using special equipment on board the vehicle to provide special priority for buses at traffic signals. A demonstration project was undertaken in 1982 for buses entering the Eglington subway station. Overall passenger delay time (transit and automobile) was reduced more than 50 percent. As a result of this successful project, another demonstration project is currently being undertaken to evaluate the effectiveness of transit priority measures on a main-line transit route. Another notable system is the VETAG system developed by Philips in the Netherlands. In this system, a transmitter on the vehicle is push-button activated to send an impulse to effect the switching of the traffic light in the desired manner.

Manual Driver Input - Sometimes, a small keyboard is provided for the driver to input information into the mobile control unit. Even though most transit properties do not like the idea of giving the driver responsibility for inputting data, other properties, such as San Mateo and San Juan, use the keyboard to input considerable data on passenger and fare counts. San Antonio is also planning on the use of a driver-activated keypad for passenger surveys.

System Time - Another possible microelectronic device that could be connected to the mobile control unit is a data unit that would display system-wide time so that all vehicles would operate their schedules according to a centrally-generated accurate system time.

Miscellaneous Sensors - Other potential options for automatic acquisition of data include automatic devices for inputting the garage number (for large properties), bus stop number (for calibrating vehicle location), and even the individual vehicle trip schedule.

Data Recording:
MOBILE TRANSIT CONTROL UNIT

Data recording in support of other information, communications and control functions is accomplished by means of a mobile transit control unit. Designed principally as a self-contained vehicle-mounted data recorder, this microprocessor-based device also provides data validation, error detection, and error correction to the data obtained from the various data acquisition sensors.

In North America, General Motors was probably the first company to develop a relatively-successful control unit for their Transit Information System (TIS) in Cincinnati. This unit was modularized with three basic components including: a cassette recorder to store data, a microprocessor-based multiprocessing system, and a proximity-sensed signpost location receiver. Based on the Motorola 6800 microprocessor, the unit also included the Intel 8748 processor for passenger counting, a real-time clock, odometer and door status board. The unit is no longer produced since General Motors ceased development of the system in late 1981.

In Los Angeles and Seattle, Dynamic Controls of Connecticut used the Intel 8080 microprocessor to develop a control unit for recording data on vehicle location, passenger counts, and emergency alarms. Data was recorded in solid state memory instead of cassette tapes. Although Dynamic Controls was on the verge of removing themselves from the market for years, they have recently affiliated themselves with London Mat Industries.

The latest control units being tested in Los Angeles are ones produced by Red Pine Instruments of Ottawa. Red Pine developed the original control unit for the Ottawa passenger counting system. The Ottawa unit was based on the Motorola 6800 microprocessor, but subsequent units for Quebec City, Portland and Calgary were based on the 6809. These units are used to record time, distance and passenger counts

and to store the data in a solid-state memory for later off-loading via an infrared data link at the bus servicing island.

Pachena Scientific and Industrial Electronics of Burnaby was recently awarded a contract to supply 63 mobile control units to Seattle Metro. These units can interface to the following types of data acquisition sensors: passenger counters, odometers, signpost receivers, radio modems, data collection equipment for extracting the data, vehicle mechanical sensors and electronic destination signs.

Gandalf Data Limited is providing its MDT 3600 transit control unit to both the CTCRO in Hull and the City of Halifax. This unit, based on the Intel 8085 microprocessor, has provision for up to seven mechanical alarm inputs as well as a silent emergency alarm. Optionally, the central dispatch processor can remotely activate four external devices under message control and two optional accessory boards can be used to provide interface circuitry for passenger counting, odometer, etc. The unit is designed to interface with modern eight-channel radios and to achieve a high-speed digital communications rate of 3600 baud per second in the 900 to 1800 Mhz band.

The Toronto Transit Commission developed their own control unit called TRUMP (Transit Universal MicroProcessor). Initial development of the TRUMP concept and related computer, electronic and radio components was carried out during 1974 and 1975. Eight buses were equipped and tested with the prototype equipment in July 1975 (13). Subsequently, 100 additional buses were equipped for large-scale testing in 1978. In January 1984, another 185 vehicles were equipped. The plan is to eventually equip the entire fleet with this unit which would monitor and control communications, location, passenger counting and other information needs. The unit which was developed by TTC staff ties into a UHF radio communication system and is produced by RMS Industrial Controls of Port Coquitlam.

Teleride/Sage of Toronto, a joint corporation that is 50 percent owned by the Government of Ontario, is also developing a Transit Information, Communications and Control System (TICCS) with funding from the Ontario Board of Industrial Leadership and Development, the Ontario Ministry of Transportation and Communications and several participating municipalities (Ottawa, Hamilton and Mississauga). TICCS is planned to be eventually a complete hardware and software package to aid in all aspects of transit. In January 1984, Teleride/Sage was developing specifications for bids to supply a mobile transit control unit for TICCS in Ontario.

In Europe, SRA Communications in Sweden, ITT Sel in Germany, Interlec in France and Italtel in Italy are a few of the companies that supply

on-board microprocessor-based control units for transit information, communications and control systems. None of the European manufacturers, however, have attempted to penetrate the North American market to any extent.

Data Transferring:
DATA AND VOICE COMMUNICATIONS

Digital communications in support of other information and control functions is accomplished by means of mobile radio communication systems.

One of the most important considerations in transit control is the ability to keep in close contact with drivers in order that disruptive events can be identified and responded to quickly and efficiently. In order to improve this contact, many transit properties have turned to radio communications. Radio communication systems consist primarily of two types -- voice radio communications and digital radio communications, with increasing use of computers and cellular systems to control the communications:

1. **Voice radio communications** involve the installation of mobile radios on the vehicles which are capable of receiving and transmitting voice messages between the vehicle and the control centre. Voice radio is limited by the number of channels that are available to the transit operator. In transit systems having over 100 buses, channel limitations usually limit the use of the system to important messages only and thus are primarily an emergency-handling device. In small transit services, such as those for disabled persons, the agency may even be forced to share channels with other users.

2. **Digital communications** involve the installation of mobile radios on transit vehicles which are capable of handling both voice and data communications. Normally, a one-way digital signal can be transmitted, but in some installations, data can be transmitted and received in both directions between the vehicle and the control centre. The one-way digital systems allow the controller to be selective in the use of voice communications where radio channels are limited (selective call system).

New York City is an example of a selective call radio system. With 4800 buses equipped, it is the largest radio-equipped bus fleet in the world. The system uses 15 radio channels and was adopted mainly as a security measure. Most newer communications systems, however, are utilizing two-way digital and voice communications. Good examples of some of the newer radio communications and control systems are found in Ottawa, Winnipeg and Toronto.

Data and Voice Communications

In September 1980, Teleride Developments Limited completed a Radio Communications Study which produced a plan for COBA (Communications, Operator and Bus Assignment), a dispatch and control system for transit. The primary objective of the COBA system, which is being implemented in Ottawa as part of the TICCS program, is to provide better communications with the buses on the street which, in turn, will improve service control (15). A radio communications system will allow bus drivers to talk to the control centre and to garages about vehicle status and location. To minimize communication time, each time the driver depresses the 'push-to-talk' button, the equipment will automatically identify the bus number, route/run number, the operator's badge number and the schedule position of the bus on the video display screens at the control centre. The driver will also be able to hit a switch on the bus to notify the control centre instantaneously of any problem or emergency situation. The transit agency would then be able to respond quickly.

At the City of Winnipeg Transit System, a new radio-communications system was opened in October 1983 (16). The system was installed by the Manitoba Telephone System with Datap Systems providing the software. The control centre consists of five controller's consoles, which work any of the four radio channels assigned to the buses. The controllers are also responsible for entering or removing buses from a 'route and run' memory bank stored in a computer which controls radio transmissions. A teleprinter logs every call made to or from control, and registers the time, console number, channel number, tower identity, bus number, run number, route name, and the priority rating of each call. Since the system has been in effect, Winnipeg Transit has been able to speed up communications relating to bus problems, traffic adjustments, reroutes, emergency handling and so on.

With the Toronto Transit Commission's Communications and Information System (CIS), the communication system is subdivided into three types of channels: voice, data and acquisition. All three channels are controlled by the system master computer and are routed through a polling controller and a base station to the vehicle. The polling controller manages all three channels for a set of vehicles as defined by the host computer (cellular system). There are two base stations connected to each polling controller. The first base station is used strictly for data transmission in order to poll the set of vehicles. This base station has a dual frequency capability in the event of problems occurring on one channel. The second base station has the dual function of voice communication and acquisition polling. Using the data channel, the polling controller polls a set of vehicles that are within a predefined area referred to as a cell. The full duplex radio has a 12.5 KHz channel step capability giving a total of 80 channels that can be used in a geographic cell pattern (cellular radio system). Data from the vehicle is stored and transmitted to

the host computer as required. The radio on the Toronto CIS system is a UHF synthesized unit designed for use specifically in automatic multi-channel cellular radio systems. The radio, produced by RMS Industrial Controls, is packaged with a microprocessor based on the Intel 8085 processor. It has both a RAM (random access memory) and EPROM (eraseable programmable read only memory) on microelectronic boards and is heavily laden with paralled input and output lines to accept keypad entries from the driver, to provide driver alert and notification tones, passenger counting, location control, real time clocks and control of all protocols on data transmission.

With increasing automatic recording of data, the question arises of whether the data must be transmitted to the control centre by radio or whether an automatic recording and storage device (such as solid-state memory) should be used on-board the vehicle. With real-time transmission, the data is available for either immediate, or later, processing. With off-line systems, the data has to be extracted either manually or with some form of data probe. Although most recent decisions (Hull, Toronto, Halifax) have been in favour of real-time digital transmission of the data, as the amount of data collected increases, there may be a need for both types of data transmission.

Until recently, the digital and voice communications market has been dominated by Motorola and General Electric, but Japanese radios are starting to appear (Koasai and Mitsubishi). The market is also fairly mature with a large percentage of transit properties already equipped with radios. The ancilliary market for cellular and computer-controlled communications systems, however, is just beginning.

Data Processing:
CENTRAL MONITORING AND CONTROL

Data collected from the on-board equipment is usually sent to a central monitoring and control facility via the digital communications network. The data is processed in the central facility, and the information is made available for real-time fleet control and for off-line reporting.

For real-time control, the collected information is presented to the controller in an appropriate display format. Usually, operational information is displayed on an out-of-tolerance, 'exception-type' basis so that fleet problems can be effectively controlled without the necessity of monitoring all fleet activity. The operational data would also be stored so that various tabular and summary reports could be prepared as required on operational conditions.

With newer installations, a modular, 'distributed processing' approach is used that gives the system a large amount of flexibility. In these systems, a microcomputer, designated as the data preprocessor, polls vehicles and retrieves and transmits data. A minicomputer (the control processor) is responsible for real-time data analysis and controls the video screen functions, while a second minicomputer (the report processor) controls data storage and retrieval, and report generation. This distributed approach allows the central control facility to be easily tailored to individual property's requirements and to be easily expanded through networking of additional processors.

In Europe, the early systems in London (BESI and CARLA), Hamburg, Paris (SECAMA) and so forth have over the years developed into sophisticated vehicle monitoring and control systems. For example, the Bus Trafic Ledning (Bus Traffic Control) System developed by SRA Communications for Stockholm is a computer-controlled system that monitors the location of vehicles, compares this information to the actual bus schedules stored in the computer and displays deviations from schedule to the central controller. Volvo Transportation Systems is also developing a comprehensive transit control system based on the technology in their taxi control system. Italtel offers the AVM 102 Central Management System, developed by Italtel-Societa Italiana Telecomunicazioni, which provides for continuous real-time monitoring and control of transit services. Interlec, a division of Matra Industries in France, also develops monitoring and control systems; as does Philips in the Netherlands; and ITT SEL and Messerschmitt-Bolkow-Blohm in Germany.

In North America, Motorola supplied the first central monitoring and control system to Chicago in March 1970. Since then, a host of manufacturers, including IAL Communications, General Railway Signal, Prior Data Sciences, AVM Systems, Fischbach and Moore Communications, Wismer and Becker, Transmax and Teleride/Sage, have attempted to penetrate the market in one capacity or another. AVM Systems supplied most of the equipment for the Los Angeles bus control system and Transmax is developing the software for the Hull system. Both the Toronto Transit Commission and the City of Halifax are developing their own systems with in-house resources.

In Canada, the Provincial Government of Ontario is heavily committed to these types of systems and is assisting in a project to develop a Transit Information, Communications and Control System (TICCS) in several participating municipalities in Ontario. The companies chosen as system integrators for the project are Teleride Developments Limited and Sage Management Consultants which are inter-related companies, both owned 50 percent by the Ontario Energy Corporation. The Ontario Board of Industrial Leadership and Development is contributing $5 million to the project over five years, with the balance

of funding coming from the Ontario Ministry of Transportation and Communications and the participating municipalities.

The proposed TICCS program is designed to produce a complete hardware and software package to aid the transit properties in planning and scheduling, internal operations, communications and control, public information, maintenance and material management, finance and administration, management information and office automation. The components of TICCS are currently in various stages of development, some are operational and some are still in the planning stage.

The market for central monitoring and control systems is extremely large but highly diversified. Every transit property appears to want to develop their own system. With so many suppliers in the North American market, it seems certain that there will be a shake-out in the near future with some suppliers withdrawing (as General Motors did in 1981). The European manufacturers have not been able to penetrate the North American market partly because of the costs involved and partly because of transit properties concern for continuing support and maintenance of any system that might be purchased.

Data Reporting:
INTERNAL MANAGEMENT INFORMATION

Three of the most important areas of internal management information to transit properties are: general management information systems, maintenance management and automated scheduling systems. These are discussed in the following paragraphs:

Management Information Systems (MIS)

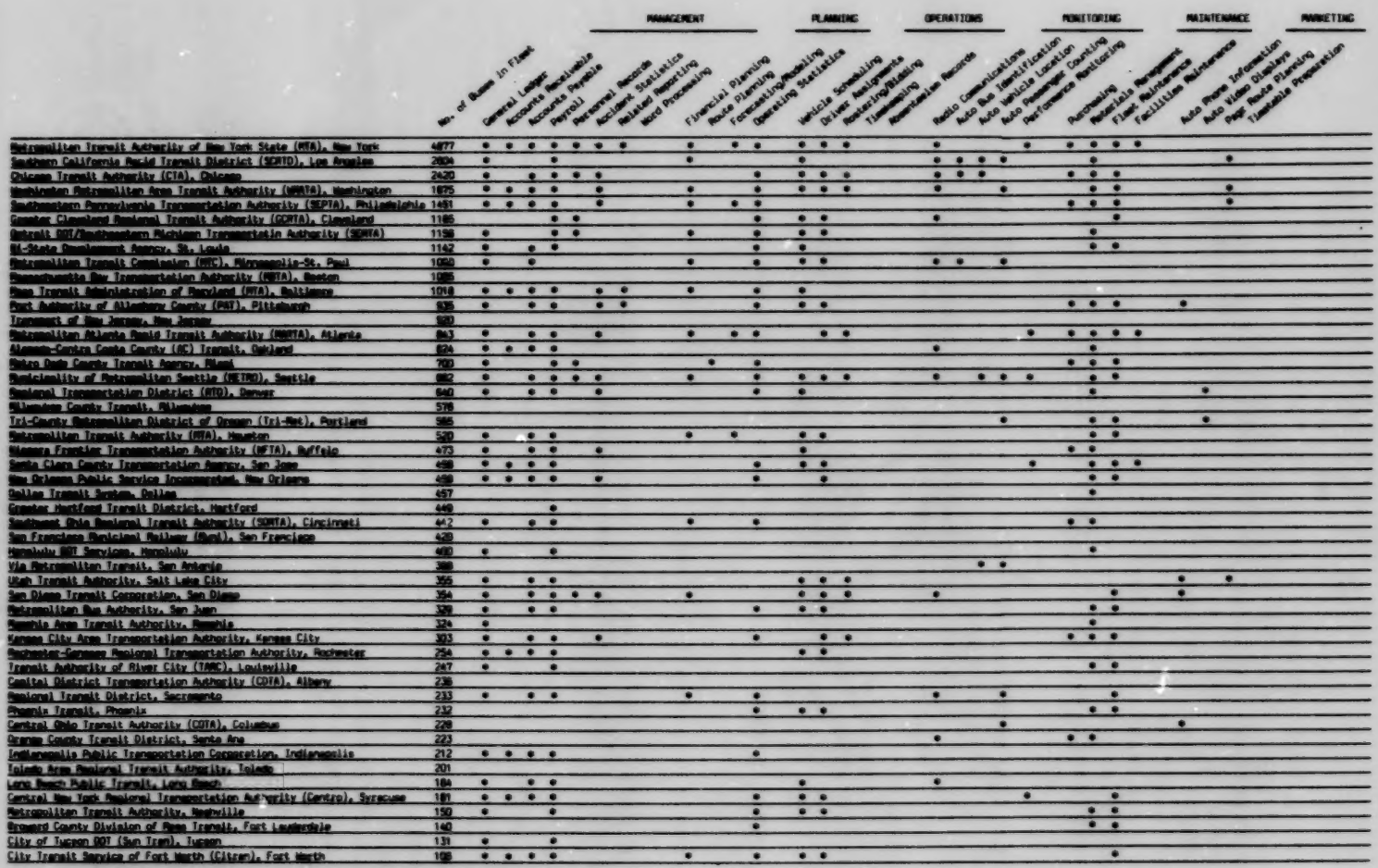
In 1970, only two transit properties in Canada, Toronto and Montreal, were using computers to any extent for internal management information systems. By 1975, there were six properties and by 1980, there were twelve properties using computers. Now, about 30 properties are making considerable use of computers for routine activities such as accounting and payroll (17). As shown in Exhibit 2, the majority of computer applications are administrative in nature. In the United States, a similar development has occurred, as shown in Exhibit 3.

General ledger, accounts payable, payroll and inventory control seem to be the first applications for many transit properties in both Canada and the United States (18), usually the result of applying a commercially-available, nonindustry-specific package from a computer systems vendor.

	No. of Buses in Fleet	MANAGEMENT: General Ledger	Accounts Receivable	Accounts Payable	Payroll	Personnel Records	Accident Statistics	Related Reporting	Word Processing	PLANNING: Financial Planning	Route Planning	Forecasting/Modelling	Operating Statistics	OPERATIONS: Vehicle Scheduling	Driver Assignments	Monitoring/Alerting	Timekeeping	Absenteeism Records	Radio Communications	Auto Bus Identification	Auto Vehicle Location	Auto Passenger Counting	Performance Monitoring	MONITORING: Purchasing	Materials Management	Fleet Maintenance	Facilities Maintenance	MAINTENANCE: Auto Phone Information	Auto Video Displays	Prep Route Planning	Timetable Preparation	MARKETING
Commission de Transport de la Communauté Urbaine de Montreal (CTCUM)	2200	•	•	•	•	•	•	•		•	•	•		•	•	•	•	•					•		•	•				•	•	
Toronto Transit Commission (TTC), Toronto	1580	•			•	•	•	•		•	•	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•			•	•	
Metro Transit Operating Company (MTOC), Vancouver	915	•	•	•	•	•		•		•			•	•	•		•	•						•	•							
Ottawa-Carleton Regional Transit Commission (OC Transpo), Ottawa	812	•	•	•	•	•	•	•		•	•	•	•	•	•		•	•	•		•		•	•				•	•	•	•	
Edmonton Transit System, Edmonton	803	•	•	•	•	•		•		•	•	•		•	•	•	•	•				•		•	•	•				•	•	
Calgary Transit System, Calgary	714	•	•	•	•	•	•	•		•		•		•	•		•	•			•			•	•						•	
City of Winnipeg Transit System, Winnipeg	546	•	•	•	•		•	•		•	•	•		•	•		•	•			•											
Commission de Transport de la Communauté Urbaine de Quebec (CTCUQ)	377	•			•	•	•	•		•		•		•	•		•					•	•									
Commission de Transport de la Rive Sud de Montreal (CTRSM)	371																															
Hamilton Street Railway Company (HSR), Hamilton	273	•				•		•		•				•	•		•	•														
City of Laval Transit Commission	251	•		•	•					•		•		•	•									•								
GO Transit, Toronto	148	•		•	•		•	•		•								•						•								
Mississauga Transit	157							•		•		•		•	•	•	•	•	•	•				•	•		•					
London Transit Commission, London	135				•																		•									
Metro Transit Commission, Halifax-Dartmouth	143	•		•	•		•							•	•									•	•							
Commission de Transport de la Communauté Regionale de l'Outaouais (CTCRO)	138	•		•	•		•	•		•				•				•	•	•												
Saskatoon Transit System	129					•												•														
Metro Transit Operating Company (MTOC), Victoria	121	•	•		•						•													•	•							
Transit Windsor	98				•													•	•	•	•										•	
Quebec Transit System	97	•	•	•	•					•								•						•	•							
Kitchener Transit	82	•	•	•		•	•	•						•	•												•					
St. John's Transportation Commission	73				•													•														
Thunder Bay Transit	67							•																								
Sudbury Transit	57																	•	•	•	•											
St. Catharines Transit Commission	56	•	•	•	•													•														
Brandon Transit	52																	•														
Communauté Regionale de Transport de Sherbrooke	43	•	•	•	•	•		•			•		•	•		•		•						•								
Kingston Transit	42				•													•														
Atomic Energy of Canada Limited, Chalk River	38				•																			•								
Oshawa Transit	38																	•														
Saint John Transit Commission	38																	•														
Guelph Transportation Commission	37																	•														
Hamilton Transit	34	•	•	•		•																					•					
West Vancouver Municipal Transportation	32	•	•	•	•			•		•				•				•						•			•					
Oakville Transit	32	•			•			•										•														
Sault Ste. Marie Transportation Commission	31																	•														
Burlington Transit	30	•	•	•	•		•			•														•								
Cornwall Transit	28																	•														
Corporation of the City of Peterborough	27																	•														
Sarnia Transit	27																	•														
Lethbridge Transit	27	•	•	•	•					•																						
Red Deer Transit	27																	•														
Corporation of the City of Cambridge	26	•	•	•	•	•		•		•	•					•		•		•												
Timmins Transit	25																															
North Bay Transit	23	•	•	•	•	•				•						•		•						•								
Fredericton Transit System	22	•	•	•	•													•														
Moncton Transit	20																	•														
Moncton Transit	20																															
Niagara Transit, Niagara Falls	18	•	•	•	•		•	•										•														
Medicine Hat Transit	18																	•														

SOURCE: Results of CUTA Questionnaire 83-8, "Current Status and Future Development of Computer Applications", March 1984.

EXHIBIT 2: APPLICATIONS OF INFORMATION TECHNOLOGY IN CANADIAN TRANSIT PROPERTIES


MANAGEMENT
PLANNING
OPERATIONS
MONITORING
MAINTENANCE
MARKETING
No. of Buses in Fleet
General Ledger
Accounts Receivable
Accounts Payable
Payroll
Personnel Records
Accident Statistics
Related Reporting
Word Processing
Financial Planning
Route Planning
Forecasting/Modeling
Operating Statistics
Vehicle Scheduling
Driver Assignments
Monitoring/Dispatching
Timekeeping
Maintenance Records
Radio Communications
Auto Bus Identification
Auto Vehicle Location
Auto Passenger Counting
Performance Monitoring
Purchasing
Materials Management
Fleet Maintenance
Facilities Maintenance
Auto Route Information
Auto Video Displays
Dept Route Planning
Timetable Preparation
Metropolitan Transit Authority of New York State (MTA), New York 4877
Southern California Rapid Transit District (SCRTD), Los Angeles 2804
Chicago Transit Authority (CTA), Chicago 2420
Washington Metropolitan Area Transit Authority (WMATA), Washington 1875
Southeastern Pennsylvania Transportation Authority (SEPTA), Philadelphia 1451
Greater Cleveland Regional Transit Authority (GCRTA), Cleveland 1185
Detroit DOT/Southeastern Michigan Transportation Authority (SEMTA) 1156
Bi-State Development Agency, St. Louis 1142
Metropolitan Transit Commission (MTC), Minneapolis-St. Paul 1050
Massachusetts Bay Transportation Authority (MBTA), Boston 1035
Mass Transit Administration of Maryland (MTA), Baltimore 1018
Port Authority of Allegheny County (PAT), Pittsburgh 935
Transport of New Jersey, New Jersey 920
Metropolitan Atlanta Rapid Transit Authority (MARTA), Atlanta 843
Alameda-Contra Costa County (AC) Transit, Oakland 824
Metro Dade County Transit Agency, Miami 700
Municipality of Metropolitan Seattle (METRO), Seattle 682
Regional Transportation District (RTD), Denver 640
Milwaukee County Transit, Milwaukee 578
Tri-County Metropolitan District of Oregon (Tri-Met), Portland 565
Metropolitan Transit Authority (MTA), Houston 520
Niagara Frontier Transportation Authority (NFTA), Buffalo 473
Santa Clara County Transportation Agency, San Jose 458
New Orleans Public Service Incorporated, New Orleans 458
Dallas Transit System, Dallas 457
Greater Hartford Transit District, Hartford 440
Southwest Ohio Regional Transit Authority (SORTA), Cincinnati 442
San Francisco Municipal Railway (Muni), San Francisco 420
Honolulu DOT Services, Honolulu 400
Via Metropolitan Transit, San Antonio 388
Utah Transit Authority, Salt Lake City 355
San Diego Transit Corporation, San Diego 354
Metropolitan Bus Authority, San Juan 328
Memphis Area Transit Authority, Memphis 324
Kansas City Area Transportation Authority, Kansas City 303
Rochester-Genesee Regional Transportation Authority, Rochester 254
Transit Authority of River City (TARC), Louisville 247
Capital District Transportation Authority (CDTA), Albany 236
Regional Transit District, Sacramento 233
Phoenix Transit, Phoenix 232
Central Ohio Transit Authority (COTA), Columbus 228
Orange County Transit District, Santa Ana 223
Indianapolis Public Transportation Corporation, Indianapolis 212
Toledo Area Regional Transit Authority, Toledo 201
Long Beach Public Transit, Long Beach 184
Central New York Regional Transportation Authority (Centro), Syracuse 181
Metropolitan Transit Authority, Nashville 150
Broward County Division of Mass Transit, Fort Lauderdale 140
City of Tucson DOT (Sun Tran), Tucson 131
City Transit Service of Fort Worth (Citran), Fort Worth 108

SOURCE: Catalog of Management Information Systems Applications Within the Transit Industry, APTA, 1981.
NOTE: Not all applications (especially radio systems) have been noted.

EXHIBIT 3: APPLICATIONS OF INFORMATION TECHNOLOGY IN AMERICAN TRANSIT PROPERTIES

Some of the more popular programs for general ledger and accounts payable include programs offered by Management Science America (MSA General Ledger System/FICS), McCormack and Dodge (General Ledger Plus), Walker and Software International. These programs are written for large mainframe computers and generally cost between $80,000 and $180,000 each. Management Science America is the largest independent software company in the United States, with much of its revenues coming from supplying software for mainframe computers, but has moved into the microcomputer area with the purchase of Peachtree Software. Peachtree developed one of the most popular accounting systems for microcomputers.

Although the microcomputer does not have a significant application as yet in internal management information systems in North American transit properties, software packages are currently being developed which will ensure its acceptance by many small and medium-sized properties in the near future (19). Much of this development work is being undertaken by the Time Support Center at Rensselaer Polytechnic Institute in Troy, New York, which is being sponsored by the United States Urban Mass Transportation Administration. The ease of use, capabilities and low cost of microcomputers will more than likely encourage further deployment by transit agencies.

Maintenance Management Systems

In the late 1960's and early 1970's, applications of maintenance management information systems were centered in the larger transit systems in North America and involved the use of large-scale, 'batch processing' programs by specialized data processing personnel on large, expensive mainframe computers. Now, with the emergence of lower-cost mini and microcomputers and operating systems that facilitate distributed processing by many users in an interactive environment, maintenance information systems are being developed for smaller transit properties.

Some of the more innovative vehicle maintenance and inventory information systems noted in the following paragraphs have either been applied or have served as a model for the design of many of the systems that exist within the transit industry.

Probably one of the first computerized maintenance systems was the Service, Inventory and Maintenance System (SIMS) developed by the Mitre Corporation for the United States Urban Mass Transportation Administration in 1973. The system was subsequently implemented at the Dallas Transit System and the Alameda-Contra Costa Transit District in Oakland. More recently, Honululu, Kansas City and Nashville adopted versions of this system.

At the Chicago Transit Authority (CTA), a highly-sophisticated, on-line maintenance management system has been in use since 1975. Its functions include reporting road calls and defects, scheduling preventive maintenance, monitoring vehicle availability, analyzing the history of vehicle repairs, and evaluating maintenance employee performance (20). Variations and refinements of this system are now under development and application at the Houston Metro and the Los Angeles Southern California Rapid Transit District (SCRTD).

The Toronto Transit Commission (TTC) implemented a materials inventory control system in the mid-70's which supported its mechanics, workshops, construction crews and other maintenance workers (21). The TTC is now developing systems to provide more automated data input into its maintenance programs. Seattle Metro has developed an on-line management information system that uses a data base management information system to perform a variety of functions, including vehicle status monitoring, inventory control, payroll and personnel accounting. Several transit properties (e.g. Portland Tri-Met, Denver RTD, Santa Clara and Orange County) have in operation on-line maintenance management information systems on minicomputers, but there is no universal system, other than SIMS, that has found wide-spread application for larger properties.

For small transit properties, there is a general-purpose management information system called TRANSPAC (capable of operating on a desk-size minicomputer) that produces management information reports on system operations, fleet maintenance, inventory status, payroll, finance and accounting as well as various statistics for reporting purposes. TRANSPAC is used in about twenty-one properties in the United States (but none in Canada), including Phoenix, Tampa, Akron, Spokane, Urbana, Stockton and Jacksonville.

Lately, programs for desk-top microcomputers (such as the IBM Personal Computer) have been developed and marketed (19). These programs, with names like HERCULES, VEMM (Vehicle Maintenance Monitor) and DDS FMS (Fleet Maintenance System), promise to bring increased capabilities at low cost to many small transit properties once they have been sufficiently tested.

Besides information reporting systems, the transit industry in North America has seen the emergence of automated data collection, data entry, and diagnostic systems to facilitate the collection and processing of vehicle service and maintenance data. Applications include on-line fuel meters and data collectors to record the fuel, oil and coolant servicing of vehicles (Dallas, Detroit and Houston), the use of employee identification cards to record job work order on-off times and parts issue and receipts (Chicago, Portland, Flint and Nashville), and on-board vehicle sensor and diagnostic systems

to facilitate the detection and trouble-shooting of maintenance problems (New York).

Cummins Engine Company has offered a diagnostic system called COMPU-CHEK since 1981 which tests and diagnoses diesel engine failures. Hamilton Test Systems of United Technologies has also developed a prototype diagnostic system called Automatic Bus Diagnostic System (ABDS). The ABDS, an expansion of an earlier product called Diesel-sense, provides diagnostics for the bus engine, transmission, air conditioning system, brake air system, lubrication system, cooling system, engine electrical system and emissions. Transit authorities in New York City, Syracuse, Flint and Nashville are contemplating installing the ABDS prototypes into their bus operations under an UMTA-funded demonstration. Potential benefits of these types of systems include a reduction in the incidence of failures and an extension of vehicle life.

Some of the new computerized systems offer real-time mechanical monitoring of vehicles. On-board microprocessors generate information that can be transferred to desk-top analyzers programmed to produce detailed reports and summaries for management. Mechanical alarms can be incorporated to warn of dangerous conditions in air or oil pressure, engine temperature and so forth. The systems can log trip data, including time spent travelling, vehicle speed and engine rpm's (like an electronic tachograph). The CTCRO in Hull is integrating some of these mechanical sensors into its vehicle control system in the form of alarms.

Automated Scheduling Techniques

Automated scheduling techniques have always held a great deal of interest for the transit industry: they can combine the data handling capabilities of computers with the data analysis needs of transit operators; they can aid in the efficient deployment of bus drivers and vehicles; and they potentially will allow for a more strategic analysis of schedules and thus provide a valuable link between transit planning and operations.

Automated scheduling programs build a set of driver runs to meet a specified set of headways on each route so as to minimize operating cost given the prevailing labour agreement. Traditionally, for a property of even modest size, this runcutting process has been extremely laborious and time-consuming as well as requiring considerable skill on the part of the schedule maker. New runs are typically generated three or four times each year, and because of the cumbersome nature of the manual process, only minor changes are made from the previous year's schedule. Once a computerized runcutting and

scheduling package and necessary data files are established for a property, alternative schedules can be tested quite quickly.

During the period of 1976-79, the Urban Transportation Research Branch (now defunct) of Transport Canada sponsored (or co-sponsored) a number of research and development projects aimed at improving the application of automated scheduling techniques in Canada. The principal focus of this work was the introduction, evaluation and further development of the RUCUS transit scheduling program developed by the Mitre Corporation for the Urban Mass Transportation Administration (22).

RUCUS was introduced and evaluated under Transport Canada sponsorship in Kitchener, Edmonton, Calgary and Halifax. In addition, further development of the RUCUS program was done in cooperation with the Halifax Transit Commission, the Toronto Transit Commission and the Ontario Ministry of Transportation and Communications. Toronto was the first city in Canada to introduce RUCUS (in the fall of 1976). Other cities that were introducing RUCUS at about the same time included: Ottawa, Vancouver and Winnipeg. Through these demonstration projects, it was generally concluded that RUCUS was a valuable scheduling tool but that improvements were required to make it more suited to user needs and abilities. Consequently, Transport Canada participated in subsequent development/demonstration projects which were designed to: improve the runcutting capabilities, reduce the data coding effort, and enhance manual schedule development techniques. The resulting Mini-Scheduler package has subsequently found fairly widespread application in both Canada and the United States.

The Mini-Scheduler package, currently offered by Teleride/Sage, is a fully-interactive computer software package. In comparison to RUCUS, it provides increased user control, interactive runcutting, greater capabilities, improved software efficiency and reporting capabilities. Mini-Scheduler is currently utilized in Toronto, Ottawa, Mississauga, and Halifax. The package is continuously being improved and modified. At the Washington Metropolitan Area Transit Authority (WMATA), one of the first installations of Mini-Scheduler, a traffic check reporting and analysis module and a jurisdictional reporting module were incorporated. In San Antonio, it was necessary to develop routines for three-piece runs which were also used in Washington, Louisville, Mississauga and Ottawa. At AC Transit in Oakland, an interactive method of assigning weekly duties (rostering) was incorporated and later used in Mississauga. In Mississauga itself the main innovation was the tying in of the scheduling system with a timeroll (exception reporting) package that allowed an interface from the scheduling function right through to payroll (23).

HATUS, another automated planning and scheduling technique, was

developed by the Montreal-based firm of GIRO Inc. in cooperation with the University of Montreal. The current HASTUS package, marketed by ATE Management in the U.S. and Volvo overseas, comprises three subsystems: HASTUS-Bus for vehicle scheduling, HASTUS-Macro for manpower and service planning and for preprocessing of vehicle data as a first step in manpower scheduling, and HASTUS-Micro for generation of operator assignments. The three subsystems are fully integrated, although it is easy to operate the HASTUS-Macro system by itself without involving other parts of the system and without disturbing the scheduling data base. HASTUS-Macro has been used extensively by Montreal and Quebec City transit authorities in contract negotiations. Parts of the package have been applied in Montreal, Quebec City, Los Angeles, Paris, Goteborg, Marseille, and Calgary. HASTUS-Micro is currently being adapted to handle four-piece runs for Stockholm, and has been implemented in Montreal, Quebec City, Hull, Singapore, Sherbrooke and Montreal South Shore.

BUS-SCHED is another automated scheduling package, offered by Transpotech Corporation Limited of Kingston and Toronto, Ontario and ATE Management in the U.S., that has been designed specifically to meet the needs of small to medium-scale transit properties. In its early development stages during the 1970's, BUS-SCHED was developed in cooperation with several transit properties. Currently, in Canada, B.C. Transit is using BUS-SCHED for operational planning purposes in over ten small communities in British Columbia, while Kitchener Transit is in the process of finalizing the implementation of BUS-SCHED. Other clients include North County Transit in San Diego and Sun Tran in Tucson.

Other very recent automated scheduling packages include RAMCUTTER by Research Applications for Management of Palo Alto, California which is being tested by Tri-Met in Portland, Muni in San Francisco and AC Transit in Oakland; and IMPACS by SRI International of Menlo Park, California which has been implemented in New York.

Some automated scheduling packages have recently been developed for application on desk-top microcomputers (like the IBM Personal Computer). DKS RUNS by DKS Associates of Oakland, California and MicroRUCUS by Comsis Corporation of Mountain View, California are two of these. HASTUS is also available on a small multi-user microcomputer and Teleride/Sage are working on a version of Mini-Scheduler for microcomputers called, appropriately, Micro-Scheduler.

While the automated scheduling techniques in some instances have been able to reduce the cost of operating a schedule slightly, the major benefits realized to date have been due to improved management and easier access to data. For example, management can readily estimate the cost of a particular change in the labour agreement

and can thus be guided effectively in union negotiations. Similarly, schedule makers can concentrate on the services being provided to the public, rather than the mechanics of runcutting. Another important benefit is discussed further in the following section - automatic bus passenger information systems. But the scheduling data base in a computerized system can also be used in vehicle monitoring and control systems and automatic passenger counting systems as the base for measuring schedule adherence.

Data Disseminating:
EXTERNAL CUSTOMER INFORMATION

Perhaps the most interesting application of microelectronics in urban transit is in the marketing area, specifically for customer information. Customer information has typically been provided by telephone operators relying on their knowledge of the system as well as printed information on specific routes. The principal problems with this approach are the length of time before an operator can be fully trained and productive, and the difficulty of organizing printed materials for easy access. Two levels of information technology have been implemented to try and overcome these problems and these are discussed in the following paragraphs:

Computer-Assisted Information

The first level involves the use of computers to store the route information for easy retrieval by the telephone operators. With these systems, access time is reduced and significant gains in telephone operator productivity can be achieved.

Two notable systems have been developed in the United States, namely the Computerized Customer Information System (CCIS) developed by the Systems Development Corporation of Santa Monica, and the Automated Information Directory System (AIDS) by the Washington Metropolitan Transit Authority. These are basically telephone information systems providing callers with their optimal point-to-point itinerary once the desired travel date, times and origin and destination information are provided. Both systems use manual call-in and answer-back procedures; that is, the caller has to dial in and enquire verbally and the call-taker responds by retrieving information via a computer terminal and then reading the information over the telephone. CCIS uses a time-sharing computer while AIDS uses a dedicated minicomputer. These systems are basically designed for transit properties with a complex transit network. Both systems have been in operation for about three years (25).

Automatic Passenger Information

The second level of technology for customer information is perhaps more commonly known. It involves the application of computerized voice response to inform the person requesting information the times of the next two buses serving the route and stop number specified by the user. These Automatic Passenger Information (API) systems use state-of-the-art synthesized voice technology to automatically answer telephone enquiries for scheduled (or actual) bus arrival times, service status and other information of interest to the public. They provide prospective transit users with scheduled bus arrival times at their specific bus stops. All bus operating schedules are stored in a computer along with a directory of bus stops. Each stop is assigned a telephone number. When a call is received, the computer automatically associates the call with the appropriate bus stop, and then responds with a voice message giving the arrival times of the next two or three buses at that stop. At important passenger boarding locations (eg. shopping centres, transfer points), video monitors (using Telidon Videotex technology) can be installed to provide visual information equivalent to that provided by the automatic telephone information system.

The concept of the automatic passenger information system was conceived and developed by the Urban Transportation Research Branch of Transport Canada and a demonstration service was inaugurated in Mississauga, Ontario in 1975. This demonstration project, called Easy Rider Information with Computerized Assistance (ERICA), was fully funded by Transport Canada in close cooperation with Mississauga Transit and a local shopping centre. The initial service was a small-scale, partially-automated system, but fully-automated operation began by late summer of 1977 and the system was expanded in early 1978 to three other routes and in August 1978 to another three routes. The system clearly demonstrated its value as a marketing tool to increase ridership, but also demonstrated considerable promise as an operational tool to increase the efficiency and economy of transit operations (26). After the demonstration ended in 1978, it became a part of the normal operation of Mississauga Transit. In about 1980, troubles began to surface with the on-board microprocessors and reliability of the equipment was a problem. These troubles were never satisfactorily overcome and, in the summer of 1982, the real-time aspect of the system was discontinued.

After the initial success of ERICA, a company, Teleride Developments Limited of Toronto, was formed to market and supply automatic passenger information systems to other transit properties based on schedule (rather than real-time) information. At present, automatic passenger information systems are operating in eight cities: Ottawa, Toronto, Mississauga, Kitchener, Brantford and Guelph in Canada; and Columbus

and Salt Lake City in the United States. An installation in San Diego was recently discontinued because of the lack of anticipated benefits. Systems in Pittsburgh and Winnipeg should be operating in the near future. Other cities that are developing their own system of automatic passenger information include Hull, Quebec and Halifax, Nova Scotia. Both of these systems are planned to be real-time systems, similar to ERICA.

One of the more successful installations is in Ottawa. In September 1980, OC Transpo introduced a version of the automatic passenger information system called '560' (named after its assigned telephone exchange number) in one part of the city. Between April 1980, when the system began operation, and January 1981, ridership was carefully monitored in both a 'test' community and a 'control' community. The minimum ridership increase due to the 560 system was found to be 2.8% overall and 8.2% in the off-peak periods. Extrapolation of these figures to the whole service area showed that the system would more than pay for itself in the first year. The estimated installation cost for the whole service area was $0.66 million and the estimated revenue due to additional riders was $1.11 million in the first year. Based on these results, OC Transpo concluded that automated passenger information must be a key component in future ridership growth in the off-peak periods because it provides the necessary customer information in sufficient detail and quantity at an acceptable cost (27).

The most recent addition in Ottawa has been the installation, at several major traffic generators, of video displays of schedule information, using the same data base and the same software, slightly modified, as the automated telephone system. The first two video installations were made in late 1982 at a local shopping centre and at the intercity bus terminal. The displays, using the high resolution colour graphics of Telidon technology, show the bus route number and name, and the number of minutes until the next two arrivals at the stop. Within the next five years, OC Transpo expects to have the video displays at all major transfer locations and at all of the stations associated with the transitways (28).

Regina Transit has also conducted an experiment with the Telidon Videotex technology in cooperation with Saskatchewan Telecommunications. Here, Videotex was used as an interactive information and transaction service in which the subscriber's home television set was utilized. To access transit information, the participants simply called up Regina Transit on their keypad. They received a graphic colour display on their television set of the local bus route, and a flashing 'blip' representing the bus as it travels the route. The information was accessed via a computer-generated map, and a simple bus locating system consisting of a transmitter on board the

vehicle and a receiver located at the terminal loop of the bus route. Upon receipt of the signal, the receiver informed the computer of the bus presence which in turn was graphically illustrated on the television screen. The 18-month trial period finished on February 7, 1984, and the results are being assessed.

In Europe, within the past year, electronic information systems have been also been gaining interest. ELSIE (Electronic Speech Information Equipment), the Transport and Road Research Laboratories bus stop system currently being tested in Bristol, announces the expected arrival time of the next bus, which is especially beneficial for the visually-impaired. London Transport has also announced that it intends to install a system of electronic indicators at bus stops. The proposed system is the same one that has been used in Nice for three years. The Nice VIDEOBUS system uses a display at the bus stop to indicate the routes serving the stop and indicator lights to show the position of buses on the routes.

All of these systems depend upon microelectronics, microprocessors and communication systems, and should be considered as the forerunner of far more extensive and sophisticated information systems.

3. CONCLUSIONS

This necessarily short review of microelectronics and urban transit may give the impression of extreme diversity and singular accomplishments. This would be misleading. The technology itself, the varied applications and the setting for the applications are interrelated. Even an individual product development -- the mobile transit control unit, for instance -- can show widespread 'ripple' effects throughout the transit system. The future with microelectronics will undoubtedly lead to some deep changes -- hinging to a large extent upon the simple technical developments which underlie the microelectronics industry.

The determining factor in the emerging pattern of microelectronic applications in urban transit is not what can be done, but what is chosen to be done. Technically, a vast range of capabilities are already available, and only the minority of technically demanding applications even approach, let alone are constrained by, the remaining technical limits.

The real factors affecting the application of microelectronics in urban transit are not technical, but economic and, to some extent, managerial. Functional areas that have benefited from the incorporation of microelectronics have done so not because of the exciting technical aspects involved, but because of the benefits they appear to offer. The major reasons for adopting these new technologies are related to economics: the enhanced system capability and reliability that they provide; the potential for manpower reductions; the improvements in quality and customer relations; and the improved system control that results. All of these contribute to the improvement in productivity of the transit system.

Conclusions

In reviewing the state-of-the-art of the application of microelectronics in urban transit, several conclusions stand out which relate to the technology, its application and the setting:

The first is that **there are several key technologies** underlying the application of microelectronics in urban transit. These are new and complex technologies which are difficult for the average person to understand. They are continuously being upgraded through research and development, with a resulting proliferation and multiplicity of hardware and software options. The key technologies cover: microprocessors, integrated circuits, computers, telemetry, digital data communications, voice messaging systems (with artificial intelligence) and so forth.

The second is that **the possibilities for application are diverse.** Almost every functional area of urban transit from planning to customer information is affected by the introduction of the key technologies. The effects of the technologies are diverse and widespread and this must be considered in initial planning by carefully considering the implications of integration. But, the technology must be fairly-well developed in each area before the benefits of integration become significant.

Thirdly, **the setting is not necessarily conducive to its adoption.** The adoption and rate of diffusion of microelectronics in urban transit is due as much to management's capabilities to adopt and adjust to the technology as it is to technical reasons. More awareness in the transit community is required of the wide range of capabilities available economically through the more rapid adoption and use of microelectronics. The dichotomy between the potential users and the suppliers has to be reduced.

Fourthly, **better integration of the technology is required,** not only to management's capabilities, but also to the capabilities and requirements of other related technologies. Any application of one of the key technologies in one area cannot be divorced from another. They are really multiple technologies, since they complement each other, and an investment in one often leads to additional commitments to others.

Finally, **long term development strategies should be considered.** It is significant that the promise and problems of microelectronics application and other technologies have hardly been discussed within the transit community. Impacts on the worker and the workplace, the upgrading of skills, the centralization of information and the resulting centralization of 'power', control and supervision -- all are items needing consideration. The adoption of microelectronics in urban transit may prove to be a critical point for some transit systems with many human and social consequences.

None of the microelectronic applications that have been described in this report, other than radio systems, has really found a widespread application. The speed of diffusion of these applications depends primarily, not upon technical factors, but upon human factors. It is not a question of what can be achieved from a technical standpoint. It is a question of what is desired, and the new technological capabilities can be harnessed to fulfill those needs. The major constraints are institutional, and the battle therefore will be between the vision of those who can see how the needs can be fulfilled, and the vision, or lack of it, of those making the decisions.

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